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THE RELATIONSHIP BETWEEN ELECTRICAL CONDUCTIVITY AND TEMPERATURE OF AVIATION TURBINE FUELS CONTAINING STATIC DISSIPATOR ADDITIVES

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THE RELATIONSHIP BETWEEN ELECTRICAL CONDUCTIVITY AND TEMPERATURE OF AVIATION TURBINE FUELS CONTAINING STATIC DISSIPATOR ADDITIVES

RELATION ENTRE LA CONDUCTIVITÉ ÉLECTRIQUE ET LA TEMPÉRATURE DES CARBURÉACTEURS CONTENANT DES ADDITIFS ANTISTATIQUES

by/par

L. Gardner, F.G. Moon

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SUMMARY

The relationship between the electrical conductivity and temperature of Canadian produced wide-cut and kerosine type aviation turbine fuels containing static dissipator additives has been evaluated. Results obtained show that the temperature/conductivity coefficient, n, in the relationship

$$\log k_t = n\,(t - t_1) + \log kt_1$$

is dependent upon several factors including (a) temperature range (b) fuel type (c) additive type.

It is recommended that the results of the evaluation be summarized and presented in the form of a test procedure which can be reference in aviation fuel specifications.

RÉSUMÉ

La relation entre la conductivité électrique et la température des carburéacteurs canadiens à large coupe et de type kérosène contenant des additifs antistatiques a été calculée. Les résultats obtenus montrent que le coefficient température/conductivité, n, dans la relation

$$\log k_t = n\,(t - t_1) + \log kt_1$$

dépend de plusieurs facteurs, notamment a) de la plage de température, b) du type de carburant et c) du type d'additif.

Il est recommandé que les résultats de l'évaluation soient résumés et présentés sous la forme d'une méthode d'essai à laquelle on puisse se reporter dans les spécifications des carburéacteurs.

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THE RELATIONSHIP BETWEEN ELECTRICAL CONDUCTIVITY AND TEMPERATURE OF AVIATION TURBINE FUELS CONTAINING STATIC DISSIPATOR ADDITIVES

1.0 INTRODUCTION

Aviation turbine fuel specifications that permit or require the use of a static dissipator additive normally quote an acceptable electrical conductivity range that is applicable at the point, time and temperature of delivery to the purchaser. Canadian Standards CAN2-3.22 (Jet B Grade) and CAN2-3.23 (1,2)* covering wide-cut and kerosine type turbine fuels respectively permit a range of 50-450 picoSiemens/metre(pS/m). ASTM Specification D1655 includes the same requirement (on an optional basis) for the Jet B, Jet A and JA-1 grades. In the Canadian Standards the relationship between conductivity and temperature is included for information purposes as follows:

$$\log k_t = a(t - t_i) + \log k_{ti}$$

Where k_t = conductivity, pS/m at $t°C$, k_{ti} = conductivity, pS/M at $t_i°C$. The slope of this straight line relationship, the temperature-conductivity coefficient, factor 'a', is quoted as being typically between 0.009 and 0.018 (based on °C).

The values for factor 'a' were obtained several years ago and were derived from conductivity measurements made with fuels containing Shell ASA-3 over a temperature range of −15°C to + 13°C. Since that time various developments have taken place which have raised the question of the continued validity of the values for 'a'. They include:

(a) Approval for use of another static dissipator additive, i.e. DuPont Stadis 450.

(b) Introduction of Tar Sands derived components into Canadian jet fuels.

(c) Problems of conductivity depletion associated with low temperature fuel storage.

At the October 6, 1981 meeting of the Canadian General Standards Board, (CGSB) Aviation Fuels and Lubricants Sub-Committee, the low temperature depletion of conductivity was discussed. One suggestion made at this meeting was that a method of specifying conductivity directly related to temperature might offer better protection under conditions where low temperature conductivity depletion could be expected. Reference was made to earlier versions of CGSB specifications which included a graph showing maximum and minimum conductivity limits over a wide temperature range.

As a result of these discussions the Fuels and Lubricants Laboratory agreed to evaluate the relationship between conductivity and temperatures of Canadian-produced aviation turbine fuels using the two approved static dissipator additives. DuPont expressed an interest in this evaluation and agreed to conduct a similar program using the same fuels covered by NRC. In addition to the determination of temperature/conductivity coefficient the NRC evaluation included work relating to mixing fuels containing both additives, re-blending with Stadis 450 and a comparison of ASA-3 and ASA-350.

The details and results of the complete NRC evaluation are presented in this report together with a brief description of the DuPont program and the DuPont data pertaining to the temperature/conductivity coefficient. Fuller details of the DuPont Program are to be found in Reference 3.

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* Numbers in parenthesis refer to references (see Para 9.0).

2.0 IDENTIFICATION OF FUELS AND ADDITIVES

Nine fuels conforming to the requirements of CAN2-3.23 (Grade Jet A-1), four fuels conforming to the requirements of CAN2-3.22 (Grade Jet B) and two fuels described as low pour point diesel fuels, supplied by various refiners, were included in the program. None of these fuels had been treated with static dissipator additive or fuel system icing inhibitor.

A sample of Stadis 450 prepared as a composite from three lots was provided by DuPont and samples of Shell ASA-3 and ASA-350 were supplied by Shell Canada. DuPont and NRC used the same additives in their respective evaluations. Shell ASA-350 (a 50% mixture of ASA-3 in solvent, marketed in Canada) was only used to compare the performance of ASA-3 with ASA-350. The temperature conductivity evaluation was made using ASA-3.

The test fuels and additives are identified as follows:

NRC Sample No. FLO	Supplier	Crude Source	Conductivity* pS/m
Jet A-1 Fuels			
81370	Irving Oil	Arabian Light Crude	2
81371	BP Canada Trafalgar (BPR No. 137)	52% MSW, 47% Syncrude 1% Vac	2
81372	BP Canada Trafalgar (BPR No. 138)	95% MSW 5% Syncrude	3
81373	Petro Canada	Hydrocracked conventional crude, mainly Middle East	0
81374	Texaco Nanticoke	Alberta Crudes 83% Texaco special +5% mixed sweet), 12% cat-cracked feedstock	0
81375	Imperial Oil Strathcona EX999 BF565	Not known	1
81376	Imperial Oil Sarnia BF535	Sweet mix, Alberta Crudes	1
81377	Imperial Oil Montreal BF549	Low Sufur blend, Light Arabian	1
82037	Chevron SS17-81	Peace River (copper sweetened clay treated)	0

NRC Sample No. FLO	Supplier	Crude Source	Conductivity* pS/m
Jet B Fuels			
81378	Imperial Oil Strathcona	Pembina federated + minor Syncrude	2
81379	Imperial Oil Sarnia BF536	Sweet mix Alberta crudes	1
81380	Imperial Oil Montreal BF550	100% Bow river	33
82036	Chevron SS16-81	45% Peace River 55% Synthetic mix (45% Condensate 25% Suncor 30% Syncrude)	3
Diesel Fuels			
81381	Imperial Oil BF566	Not known	16
81382	Imperial Oil BF560	Not known	6

* Slightly higher values were recorded by DuPont and this is attributed to sample container effects.

Additives	Supplier	Name	Quantity
81383	DuPont	Stadis 450 (4400-115)	4 oz
81384	Shell Canada	ASA-350	1 quart
81385	Shell Canada	ASA-3	1 quart

3.0 EXPERIMENTAL PROGRAM

3.1 Test Fuels and Additive Distribution

All test fuels were initially sent to NRC and three litres of each were transferred to pre-cleaned one US gallon epoxy-lined cans and shipped to DuPont. Portions of the ASA-3 and ASA-350 supplied by Shell Canada were also sent to DuPont who in return supplied the Stadis 450.

3.2 Measurement of Electrical Conductivity

The Emcee Model 1152 digital conductivity meter was used for conductivity measurements following the procedure described in ASTM Method D2624.

3.3 Preparation and Storage of Test Fuels (Temperature/Conductivity Coefficient Determination)

The procedure used by NRC to obtain a range of conductivities was different to that adopted by DuPont. The NRC approach was to add specific quantities of additive to each fuel whereas DuPont treated each fuel to achieve as closely as possible equilibrated conductivities of 100 ± 50 pS/m and 400 ± 50 pS/m.

3.3.1 NRC Procedure

One imperial quart (1.1L) wide-mouth paint cans were used for blending and storing the fuels. These cans were pre-cleaned by successive rinses of isopropanol, toluene and test fuel. One litre portions of each test fuel were added to a sufficient number of cans to allow for three additive levels for each of the two additives plus one blank.

The two additives were diluted with toluene to give a final stock solution of 1,000 ppm (mg/1) so that 1-ml added to a litre of fuel was equivalent to 1 ppm (mg/1). Additive levels of 0.5 ppm (mg/1), 1.0 ppm (mg/1) and 2.0 ppm (mg/1) were used for each additive.

After preparation the fuels were stored at room temperature (approximately 20°C) and initial conductivities recorded one day after additive treatment. The room temperature storage was continued with periodic conductivity measurements until stabilization of the conductivity was considered to have been established (approximately three weeks). The fuels were then transferred to a cold chamber and cooled in stages to approximately 3°C, -18°C and -33°C with conductivities being recorded after a minimum storage period of two days. The fuels were then restored at room temperature and conductivities again measured. The kerosine (Jet A-1) and diesel fuels were then exposed to a high temperature/room temperature cycle. Because of the large number of samples involved it was not possible to process all the fuels in one batch and some slight variation in length of storage under a particular condition resulted. Actual storage times for the various fuels was as follows:

Sample Numbers FLO	Time (days) at Temperature (Approx.)						
	20°C	3°C	-18°C	-33°C	20°C	42°C	20°C
81370 to 81374	22	4	2	3	2	2	3
81375 to 81377 82037, 81381	23	3	2	2	3	2	2
81282	22	2	2	2	2	2	10
81378 to 81380	22	2	2	2	4	—	—

3.3.2 DuPont Procedure (Summary)

The procedures used by DuPont that differed significantly from those by NRC were:

(a) The fuels were stored in one US pint Teflon-resin bottles.

(b) The fuels were treated with Stadis 450 and ASA-3 to achieve two conductivity levels. This process often requiring more than one additive treatment. After the final treatment the samples were allowed to stand in the dark for 12-20 days at room temperature.

(c) Temperature cycling was the opposite to that used by NRC insomuch as the initial change was from room temperature to high temperature. Temperature cycling at the following approximate levels was used: (Initial 20°C, 43°C, 20°C, 4°C, -18°C, -34°C, 20°C (Final). All samples were stored overnight under each temperature condition.

(d) All fuels were subjected to the high temperature (43°C) condition.

3.4 Other Evaluation (NRC)

3.4.1 Effect of Mixing Fuels Containing Different Static Dissipator Additives

The fuels that had been through the temperature cycling program (Para. 3.3) were used to determine the effect on conductivity of mixing additives. 500-ml portions of fuel containing Stadis 450 were mixed with 500-ml portions of fuel containing ASA 3. In some cases the base fuels were the same and in other cases different. Conductivity measurements were made at room temperature and after stabilization the fuels were cooled progressively to 4°C, -19°C, -34°C and restored to room temperature. Jet A-1 and diesel fuels were also subjected to a temperature of 43°C. The results of this part of the evaluation are presented in Tables 9, 10 and 11.

3.4.2 Effect of Redoping Fuels with Stadis 450

Because of absence of data relating to the effect of redoping fuels with the relatively newly approved Stadis 450 a brief program was carried out to assess this effect using some of the fuels from the temperature cycling program (Para. 3.3). Selected fuels were chosen and various redoping concentrations used. The results of this part of the evaluation are presented in Tables 12 and 13.

3.4.3 Comparison of ASA-3 and ASA-350

Selected fuels were treated with ASA-350 and the conductivity response measured in a similar manner to that used for ASA-3 including temperature cycling. The results obtained were compared with the original evaluation of ASA-3. The results obtained are presented in Tables 14 and 15.

4.0 DATA TREATMENT

Temperature/conductivity coefficients were calculated by NRC and DuPont using the relationship:

$$\log_{10} k_{t_1} = n^*(t_1 - t_2) + \log_{10} k_{t_2}$$

$$n = \frac{\log_{10} k_{t_1} - \log_{10} k_{t_2}}{t_1 - t_2}$$

* n has been used for clarity instead of 'a' referenced in Para. 1.0.

where n = temperature/conductivity coefficient

k_{t_1} = conductivity (pS/m) at t_1 °C

k_{t_2} = conductivity (pS/m) at t_2 °C

The NRC data was used to calculate values for the temperature/conductivity coefficient n over various temperature ranges as follows:

-33 to 42°C (except for wide-cut fuels)
42 to 23°C (except for wide-cut fuels)
23 to -33°C
23 to -18°C
23 to 3°C
3 to -18°C
-18 to -33°C

DuPont arbitrarily based their coefficients on conductivities at 43°C versus 4°C and 4°C versus -24°C.

Both laboratories obtained coefficients by linear regression analysis of data points at the following temperatures:

20°C
43°C
20°C
4°C
-18°C
-34°C
20°C

The results of the linear regression analysis which are included in the Tables in Appendix B, showed a high degree of correlation as evidenced by the coefficients of determination (R^2) which were generally greater than 0.95. In two instances with FLO81370 values of R^2 of 0.84 and 0.87 were obtained. A similar reduction in the degree of correlation for this fuel was noted by DuPont.

5.0 RESULTS

5.1 Overall Conductivity/Temperature Data

The conductivities measured over various temperature ranges are presented in tabular form in Appendix A. Tables are identified as follows:

NRC Data

Table A-1: Electrical Conductivities vs Temperature: Kerosine Fuels
Table A-2: Electrical Conductivities vs Temperature: Wide-Cut Fuels
Table A-3: Electrical Conductivities vs Temperature: Diesel Fuels

DuPont Data (from Ref. 3)

Table A-4: Electrical Conductivities vs Temperature: Kerosine Fuels
Table A-5: Electrical Conductivities vs Temperature: Wide-Cut Fuels
Table A-6: Electrical Conductivities vs Temperature: Diesel Fuels

5.2 Temperature/Conductivity Coefficients (n and nR)

The temperature conductivity coefficients (n) calculated over various temperature ranges and the values of nR obtained by linear regression analysis are presented in tabular form in Appendix B. Tables are identified as follows:

NRC Data

Table B-1: Temperature/Conductivity Coefficients: (Jet A-1 + Stadis 450)

Table B-2: Temperature/Conductivity Coefficients: (Jet A-1 + ASA-3)

Table B-3: Temperature/Conductivity Coefficients: (Jet B + Stadis 450)

Table B-4: Temperature/Conductivity Coefficients: (Jet B + ASA-3)

Table B-5: Temperature/Conductivity Coefficients: (Diesel Fuels)

DuPont Data (from Ref. 3)

Table B-6: Temperature/Conductivity Coefficients: (Jet A-1)

Table B-7: Temperature/Conductivity Coefficients: (Jet B)

6.0 DISCUSSION OF RESULTS

6.1 General

Past experience with the laboratory evaluation of static dissipator additives in hydrocarbon fuels has shown that apparently abnormal behaviour in terms of conductivity response and stability can sometimes occur. This behaviour is not usually related to any deficiency in additive quality but is in most instances due to effects contributed by the fuel and/or sample handling. It should be remembered that while relatively large numbers are used to express conductivity requirements i.e. 50-450 pS/m, the conductivities are extremely low (1 pS/m = 10^{-12} mhos/m) and easily susceptible to influence from trace contaminants both in the fuel and fuel containers as well as variations in fuel composition. In addition the additives can be adsorbed on surfaces in contact with the fuel causing a significant reduction in conductivity[4]. Conclusions derived in a conductivity evaluation program therefore have to be general in nature and are not necessarily applicable to every fuel handled in every situation.

The main purpose of the current program was to determine the temperature/conductivity relationship of Canadian produced jet fuels using the two approved static dissipator additives. There was no intent in the program to compare the overall efficiencies of the additives apart from any comparison required to explain their temperature/conductivity behaviour in a particular fuel.

6.2 Additive Response at Room Temperature

The results obtained by NRC presented in Table A-1, A-2 and A-3 show the conductivities attained at various temperaturees for three dosage levels of each additive. These have been used to calculate the response, in terms of mg/l per 100 pS/m at room temperature (approximately 20°C). These calculated values which are shown in Table 1 include two values for each dosage level representing the response after 24 hours and after 22 days. The concentrations for the two additives cannot be compared against each other since these values represent the total additive concencntration and not the active ingredient component. A comparison of NRC and DuPont data relating to additive response is included in Table 2.

TABLE 1

ADDITIVE CONCENTRATIONS (CALCULATED) TO PRODUCE 100 pS/m AT ROOM TEMPERATURE

Additive Conc. Sample No. FLO	Stadis 450, mg/1/100 pS/M at ≈ 20°C						ASA-3, mg/1/100 pS/m at ≈ 20°C					
	0.5		1.0		2.0		0.5		1.0		2.0	
	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(i)
81370	2.2	2.9	1.7	4.2	1.3	2.0	0.4	0.7	0.3	0.4	0.3	0.3
81371	0.4	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.5
81372	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
81373	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3
81374	1.0	1.3	0.9	0.9	0.7	0.7	0.5	0.4	0.5	0.5	0.5	0.4
81375	0.5	0.6	0.5	0.5	0.5	0.5	0.2	0.1	0.2	0.1	0.3	0.2
81376	0.6	1.1	0.5	0.8	0.5	0.6	0.4	0.2	0.4	0.2	0.4	0.2
81377	1.9	2.1	1.5	1.8	1.0	1.1	0.9	0.8	0.7	0.7	0.7	0.6
82037	1.1	2.4	1.0	1.2	0.7	0.8	0.4	0.6	0.3	0.4	0.3	0.3
Average	**0.9**	**1.3**	**0.8**	**1.2**	**0.7**	**0.8**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
81378	0.3	0.6	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
81379	0.3	0.5	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
81380	0.4	0.5	0.5	0.6	0.5	0.6	0.2	0.2	0.2	0.2	0.2	0.2
82036	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	—	—
Average	**0.3**	**0.5**	**0.3**	**0.4**	**0.3**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**

TABLE 2

COMPARISON OF NRC AND DUPONT DATA, AVERAGE CONCENTRATIONS TO PRODUCE 100 pS/m

Fuel Type and Additive	NRC						DuPont (iii)	
	0.5		1.0		2.0		Low	High
	(i)	(ii)	(i)	(ii)	(i)	(ii)		
Jet A-1 + Stadis 450	0.9	1.3	0.8	1.2	0.7	0.8	1.59	0.87
Jet A-1 + ASA-3	0.4	0.4	0.4	0.4	0.4	0.4	0.42	0.40
Jet B + Stadis 450	0.3	0.5	0.3	0.4	0.3	0.4	0.55	0.44
Jet B + ASA-3	0.2	0.2	0.2	0.2	0.2	0.2	0.25	0.17

(i) Based on conductivity measured after 24 hours.
(ii) Based on conductivity measured after 22 days.
(iii) Based on equilibrated conductivities. "Low" and "High" refer to the two levels to which the fuels were blended.

The results presented in Table 1 show:

(a) The concentration values for wide-cut fuels for both additives are approximately half those required for kerosines. This would be expected because of the significant difference between the viscosities of the two fuel types.

(b) There is a noticeable spread between the concentrations required for individual kerosine fuels to produce 100 pS/m. This difference is not so noticeable with wide-cut fuels. Examination of the inspection data supplied by fuel suppliers for the test fuels does not reveal any obvious difference in properties between any of the fuels. The crude source data also does not provide any indication as to reasons for the different response. The possible effects of crude source, particularly in relation to the use of Tar Sands derived product is a subject of a separate discussion (see Para. 6.5).

(c) A comparison between the concentrations required to produce 100 pS/m after 24 hours and 22 days shows that ASA-3 has a greater tendency to continue reacting with time than Stadis 450.

(d) Table 2 shows that the additive concentrations to produce 100 pS/m calculated from the NRC and DuPont results showed good agreement.

6.3 Additive Response at Low Temperature

The conductivities measured at very low temperatures (approx. - 33°C) shown in Tables A-1 and A-2 were examined and an estimate made of the approximate additive concentration required to produce a conductivity of 50 pS/m at - 33°C. The values are shown in Table 3. The conductivities at - 33°C were also compared with the original conductivities at room temperature (Comment 6.3(c)).

TABLE 3

APPROXIMATE ESTIMATED ADDITIVE CONCENTRATIONS TO PRODUCE A 50 pS/m CONDUCTIVITY AT - 33°C

Sample No. FLO	mg/1 Additive Estimated to Achieve 50 pS/m at - 33°C	
	Stadis 450	ASA-3
Kerosine, Jet A-1		
81370	2.0(12)*	1.5
81371	1.0	1.3
81372	0.8	0.8
81373	1.0	0.8
81374	2.0(22)	2.0
81375	2.5	1.0
81376	2.0	1.3
81377	3.5	3.5
82037	3.0	2.0
Wide-Cut Jet B		
81378	1.0	0.8
81379	0.5	0.4
81380	1.3	0.5
82036	< 0.5	< 0.5

* Values in parenthesis actual conductivities at cited concentrations.

The following comments can be made:

(a) The estimated concentration of additive required to produce 50 pS/m at −33°C varies considerably from fuel to fuel with, as would be expected, those fuels with poorer response at room temperature showing the same tendency.

(b) The concentration of additive in some cases is in excess of the specification maximum i.e. 1 mg/1 for ASA-3 and 3 mg/1 for Stadis 450. To achieve protection in the very limited number of cases where −33°C is reached the fuel may require re-doping.

(c) The loss in conductivity at lower temperature is generally slightly more severe with ASA-3. This observation is reflected in the actual temperature/conductivity coefficients discussed in Para. 6.4.

6.4 Temperature/Conductivity Coefficient (n and nR values)

The calculated temperature/conductivity coefficients (n) including those obtained by linear regression analysis (nR) have been summarized (NRC and DuPont data) and present in tabular form as follows:

Table 4: Average Temperature/Conductivity Coefficients — Jet A-2 Fuels
Table 5: Average Temperature/Conductivity Coefficients — Jet B Fuels
Table 6: Comparison NRC and DuPont nR Values
Table 7: Relation of Coefficient n to Temperature — Jet A-1 Fuels
Table 8: Relation of Coefficient n to Temperature — Jet B Fuels

TABLE 4

AVERAGE TEMPERATURE/CONDUCTIVITY COEFFICIENTS — JET A-1 FUELS

Sample No. FLO	Stadis 450					ASA-3				
	NRC			DuPont		NRC			DuPont	
	High	Med.	Low	High	Low	High	Med.	Low	High	Low
81370	0.012	0.016	0.018	0.0116	0.0150	0.015	0.013	0.012	0.0132	0.0142
81371	0.011	0.011	0.011	0.0111	0.0125	0.012	0.012	0.012	0.0121	0.0159
81372	0.009	0.010	0.011	0.009	0.0106	0.013	0.013	0.014	0.0127	0.0134
81373	0.008	0.009	0.010	0.0067	0.0123	0.012	0.013	0.016	0.0126	0.0089
81374	0.016	0.016	0.016	0.0135	0.0144	0.016	0.016	0.016	0.0150	0.0140
81375	0.016	0.017	0.016	0.0142	0.0175	0.019	0.017	0.016	0.0190	0.0135
81376	0.013	0.014	0.014	0.0121	0.0148	0.015	0.016	0.015	0.0193	0.0125
81377	0.011	0.010	0.013	0.0113	0.0091	0.015	0.014	0.014	0.0167	0.0163
82037	0.013	0.013	0.015	0.0147	0.0142	0.017	0.016	0.014	0.0170	0.0183
Average	0.012	0.013	0.014	0.0116	0.0134	0.015	0.014	0.014	0.0153	0.0141
Minimum	0.008	0.009	0.011	0.0009	0.0091	0.012	0.012	0.012	0.0121	0.0089
Maximum	0.016	0.017	0.018	0.0147	0.0175	0.019	0.017	0.016	0.0193	0.0183

TABLE 5

AVERAGE TEMPERATURE/CONDUCTIVITY COEFFICIENTS — JET B FUELS

Sample No. FLO	Stadis 450					ASA-3				
	NRC			DuPont		NRC			DuPont	
	High	Med.	Low	High	Low	High	Med.	Low	High	Low
81378	0.012	0.013	0.011	0.0121	0.0107	0.017	0.018	0.017	0.0165	0.0175
81379	0.009	0.010	0.010	0.0091	0.0087	0.013	0.013	0.014	0.0133	0.0132
81380	0.012	0.013	0.015	0.0090	0.0077	0.016	0.016	0.016	0.0149	0.0175
82036	0.003	0.003	0.003	0.0037	0.0066	0.012	0.010	0.011	0.0097	0.0092
Average	**0.009**	**0.010**	**0.010**	**0.0085**	**0.0084**	**0.015**	**0.014**	**0.015**	**0.0136**	**0.0144**
Minimum	**0.003**	**0.003**	**0.003**	**0.0037**	**0.0066**	**0.012**	**0.010**	**0.011**	**0.0097**	**0.0092**
Maximum	**0.012**	**0.013**	**0.015**	**0.0121**	**0.0107**	**0.017**	**0.018**	**0.017**	**0.0165**	**0.0175**

TABLE 6

COMPARISON OF NRC AND DUPONT nR VALUES

nR	Stadis 450					ASA-3				
Sample No. FLO	NRC			DuPont		NRC			DuPont	
	Low	Med.	High	Low	High	Low	Med.	High	Low	High
Jet A-1										
81370	0.018	0.016	0.012	0.015	0.012	0.012	0.013	0.015	0.014	0.013
81371	0.011	0.011	0.011	0.013	0.011	0.012	0.012	0.012	0.016	0.012
81372	0.011	0.010	0.009	0.011	0.009	0.014	0.013	0.013	0.013	0.013
81373	0.010	0.009	0.008	0.012	0.007	0.016	0.013	0.012	0.009	0.013
81374	0.016	0.016	0.016	0.014	0.014	0.016	0.016	0.016	0.014	0.015
81375	0.016	0.017	0.016	0.018	0.014	0.016	0.017	0.019	0.014	0.019
81376	0.014	0.014	0.013	0.015	0.012	0.015	0.016	0.015	0.013	0.019
81377	0.013	0.010	0.011	0.009	0.011	0.014	0.014	0.015	0.016	0.017
82037	0.015	0.013	0.013	0.014	0.015	0.014	0.016	0.017	0.018	0.017
Average	**0.014**	**0.013**	**0.012**	**0.013**	**0.012**	**0.014**	**0.014**	**0.015**	**0.014**	**0.015**
Minimum	**0.011**	**0.009**	**0.008**	**0.009**	**0.007**	**0.012**	**0.012**	**0.012**	**0.009**	**0.012**
Maximum	**0.018**	**0.017**	**0.016**	**0.018**	**0.015**	**0.016**	**0.017**	**0.019**	**0.018**	**0.019**
Jet B										
81378	0.011	0.013	0.012	0.011	0.012	0.017	0.018	0.017	0.018	0.017
81379	0.010	0.010	0.009	0.009	0.009	0.014	0.013	0.013	0.013	0.013
81380	0.015	0.013	0.012	0.008	0.009	0.016	0.016	0.016	0.018	0.015
82036	0.003	0.003	0.003	0.007	0.004	0.011	0.010	0.012	0.009	0.010
Average	**0.010**	**0.010**	**0.009**	**0.008**	**0.009**	**0.015**	**0.014**	**0.015**	**0.015**	**0.014**
Minimum	**0.003**	**0.003**	**0.003**	**0.007**	**0.004**	**0.011**	**0.010**	**0.012**	**0.009**	**0.010**
Maximum	**0.015**	**0.013**	**0.012**	**0.011**	**0.012**	**0.017**	**0.018**	**0.017**	**0.018**	**0.017**

TABLE 7

AVERAGE TEMPERATURE/CONDUCTIVITY COEFFICIENTS RELATED TO TEMPERATURE — JET A-1 FUELS

Temperature Range, °C	Additive	NRC				DuPont		
		High	Med.	Low	Average	High	Low	Average
42 to -32	Stadis 450 ASA-3	0.013 0.014	0.014 0.015	0.014 0.015	0.014 0.015	0.012 0.015	0.014 0.014	0.013 0.015
42 to 23	Stadis 450 ASA-3	0.009 0.011	0.010 0.011	0.011 0.011	0.010 0.011	0.009 0.010	0.010 0.009	0.009 0.010
23 to -33	Stadis 450 ASA-3	0.013 0.016	0.015 0.016	0.015 0.017	0.014 0.016	0.013 0.017	0.015 0.015	0.014 0.016
23 to -18	Stadis 450 ASA-3	0.013 0.014	0.012 0.014	0.013 0.014	0.013 0.014	0.011 0.014	0.012 0.014	0.012 0.014
23 to 3	Stadis 450 ASA-3	0.013 0.013	0.012 0.013	0.014 0.013	0.013 0.013			
3 to -18	Stadis 450 ASA-3	0.013 0.015	0.013 0.017	0.013 0.017	0.013 0.016			
-18 to -33	Stadis 450 ASA-3	0.018 0.021	0.019 0.021	0.020 0.021	0.019 0.021			

TABLE 8

AVERAGE TEMPERATURE/CONDUCTIVITY COEFFICIENTS RELATED TO TEMPERATURE — JET B FUELS

Temperature Range, °C	Additive	NRC				DuPont		
		High	Med.	Low	Average	High	Low	Average
42 to -33	Stadis 450 ASA-3					0.009 0.014	0.009 0.015	0.009 0.014
42 to 23	Stadis 450 ASA-3					0.008 0.008	0.008 0.009	0.008 0.009
23 to -33	Stadis 450 ASA-3	0.009 0.016	0.011 0.011	0.011 0.011	0.010 0.013	0.009 0.015	0.009 0.016	0.009 0.016
23 to -18	Stadis 450 ASA-3	0.008 0.013	0.008 0.013	0.010 0.014	0.009 0.013	0.008 0.013	0.007 0.012	0.007 0.013
23 to 3	Stadis 450 ASA-3	0.009 0.009	0.011 0.011	0.013 0.013	0.011 0.011			
3 to -18	Stadis 450 ASA-3	0.007 0.015	0.009 0.015	0.010 0.015	0.009 0.015			
-18 to -33	Stadis 450 ASA-3	0.014 0.020	0.014 0.019	0.012 0.019	0.013 0.019			

Examination of Tables 4 to 8 shows:

(a) The average values for n presented in Tables 4 and 5 can be summarized as follows:

Jet A-1 + Stadis 450

Range: 0.008 to 0.018, Average 0.013 (NRC)
Range: 0.009 to 0.018, Average 0.013 (DuPont)

Jet A-1 + ASA-3

Range: 0.012 to 0.019, Average 0.014 (NRC)
Range: 0.009 to 0.018, Average 0.015 (DuPont)

Jet B + Stadis 450

Range: 0.003 to 0.015, Average 0.010 (NRC)
Range: 0.004 to 0.012, Average 0.009 (DuPont)

Jet B + ASA-3

Range: 0.010 to 0.018, Average 0.015 (NRC)
Range: 0.010 to 0.018, Average 0.014 (DuPont)

(b) The average values for nR presented in Table 6 can be summarized as follows:

Jet A-1 + Stadis 450

Range: 0.008 to 0.018, Average 0.013 (NRC)
Range: 0.007 to 0.018, Average 0.013 (DuPont)

Jet A-1 + ASA-3

Range: 0.012 to 0.019, Average 0.014 (NRC)
Range: 0.009 to 0.019, Average 0.015 (DuPont)

Jet B + Stadis 450

Range: 0.003 to 0.015, Average 0.010 (NRC)
Range: 0.007 to 0.012, Average 0.009 (DuPont)

Jet B + ASA-3

Range: 0.010 to 0.018, Average 0.015 (NRC)
Range: 0.009 to 0.018, Average 0.014 (DuPont)

(c) The temperature/conductivity coefficients (n and nR) were lower for Stadis 450 compared with ASA-3. This is due to greater percentage loss in conductivity that takes place with ASA-3 on exposure to low temperatures (see Para. 6.3(c)).

(d) The temperature/conductivity coefficients (n and nR) were lower for wide-cut fuels compared with kerosine fuels and diesel fuels, with diesel fuels being the highest. This is due to the influence of fuel viscosity.

(e) There was a wider spread between both n and nR values for wide-cut fuels compared with kerosine when the results presented in Appendix B are compared. This is attributed to the wider-boiling range of wide-cut fuels allowing a more varied composition. This difference is not so noticeable when average values are compared.

(f) The effect of temperature on n as summarized in Tables 7 and 8 shows that for all fuel and additive combinations n values are higher at lower temperatures and lower at higher temperatures.

(g) In a similar manner the nR values were an approximate average of the high temperature (23° to 42°C) and low temperature (23° to -33°C) coefficients.

(h) The total data related to temperature effects on coefficient n can be summarized to give the following approximate values for three temperature ranges:

	Jet A-1		Jet B	
	Stadis 450	ASA-3	Stadis 450	ASA-3
Extreme low (-18 to -33°C)	0.019	0.021	0.013	0.019
High (23 to 42°C)	0.010	0.011	0.008	0.009
Low (-33 to 23°C)	0.014	0.016	0.010	0.015
nR	0.013	0.014	0.009	0.014

6.5 Effect of Crude Source Upon Conductivity

The information received regarding crude sources used to produce individual fuels indicated that very few samples contained any significant amount of Tar Sands product. Insufficient data was therefore to be available to establish any definite trends produced by such fuels. As previously stated (Para. 6.2 (b)) a general examination of crude sources and inspection data did not show any significant property that could be related to the variation in additive concentrations required to produce 100 pS/m. Similarly the absence of any definite trends can be extended to the effect upon temperature/conductivity coefficients.

It is interesting however to compare two fuels from one refinery i.e. FLO81371 and 81372. The reported crude sources and other properties are shown:

NRC Sample No.	FLO81371	FLO81372
Batch No.	BPR 137	BPR 138
Date taken	Nov. 13, 1981	Nov. 26, 1981
Crude Source	52% MSW 47% Syncrude 1% Vac	95% MSW 5% Syncrude
Aromatics	23.5	17.2
Density	0.8186	0.8022
Freeze Point, °C	-56	-54
Color	+29	+30
Flash Point, °C	51	46
mg/1 additive to produce 100 pS/m at 20°C		
(i) Stadis 450	0.4	0.3
(ii) ASA-3	0.5	0.3
nR (ASA-3)	0.012	0.013
nR (Stadis 450)	0.011	0.010
Original conductivity pS/m at 20°C	2	3

A comparison of the conductivity properties of the two fuels shows no significant trend compared to the variations noted amongst *all* fuels. Considering the similarity (apart from Syncrude content) of the two fuels in question, however, it is interesting to note that FLO81371 requires a higher concentration of both additives to achieve 100 pS/m. This could also be related to aromatic content since the Tar Sands derived fuel contains 23.5% aromatics compared with 17.2% for FLO81372. All other aviation fuels in the program contained less than 20% aromatics.

The only other fuel with a significant amount of Tar Sands derived product was a Jet B fuel (FIO82036) containing 55% Synthetic Mix and which had an aromatic content of 15.7%. This fuel showed remarkably good response with both additives.

The effect of crude source upon conductivity response would therefore appear to be unpredictable and this unpredictability is emphasized by the performance of FLO81370 which is a Jet A-1 fuel derived from a seemingly good crude, i.e. Arabian Light. This fuel was found by both NRC and DuPont to have a poor response to Stadis 450 and the linear regression analysis had a lower coefficient of determination, i.e. 0.792 (DuPont) and 0.83 (NRC), than all other samples. It is also interesting to note that FLO81377, another Jet A-1 derived from Arabian Light crude had a poorer than average response to both additives.

6.6 Effect of Mixing Additives

The effect of mixing fuels containing ASA-3 and Stadis 450 is shown in Tables 9, 10 and 11. This effect was quite varied and it would be impossible from the results presented in the tables to establish any definite pattern of behaviour. The results can be summarized as follows:

(a) Aviation Kerosine (Jet A-1)

A comparison of the predicted and initially measured conductivity of seven blends showed that one blend gave a marked increase, four blends behaved as predicted and two blends were lower. All blends lost 25-30% conductivity during subsequent storage at room temperature. High and low temperature cycling produced a further significant loss with two blends.

(b) Wide-Cut (Jet B)

A comparison of the predicted and initially measured conductivity of five blends showed that one blend behaved as predicted, three blends showed significantly lower values and on a slightly lower value. All blends showed reasonable conductivity stability during subsequent room and low temperature storage.

(c) Diesel Fuels

All three blends gave higher than predicted initial conductivities and all experienced approximately equivalent losses during subsequent room, low and high temperature storage.

TABLE 9

ELECTRICAL CONDUCTIVITY OF MIXED ADDITIVE FUELS (KEROSINE TYPE)

Sample No. FLO \ Temp. °C	Electrical Conductivity, pS/m					
	22° A	26° B	26° C	20° D	25° E	21° F
81370 (2 ppm Stadis 450) 81370 (2 ppm ASA-3)	45 454*	41 189	185(115)	137	124	103
81370 (2 ppm Stadis 450) 81371 (2 ppm ASA-3)	45 387	41 435	243(238)	176	136	104
81372 (1 ppm Stadis 450) 81372 (1 ppm ASA-3)	302 325	326 311	290(318)	221	225	204
81373 (1 ppm Stadis 450) 81374 (1 ppm ASA-3)	191 181	189 84	88(142)	66	77	64
81375 (1 ppm Stadis 450) 81375 (1 ppm ASA-3)	173* 736*	158 637	387(398)	272	282	241
81376 (1 ppm Stadis 450) 82037 (1 ppm ASA-3)	122* 164*	98 84	38(91)	27	34	30
82037 (1 ppm Stadis 450) 82037 (1 ppm ASA-3)	39* 164*	37 84	58(60)	41	44	38

*23°C

A: Conductivities as measured at end of temperature cycling program (April/May 1982).

B: Conductivities as measured immediately prior to mixing (August 1982).

C: Conductivity measured immediately after mixing equal volumes of each fuel. Values in parenthesis are calculated from B on basis of 50:50 mix.

D: Conductivity measured approximately two weeks after mixing.

E: Conductivity measured after cooling through 5°C, -19°C and -34°C cycles and restoring to room temperature.

F: Conductivity measured two days after heating to 43°C and restoring to room temperature.

TABLE 10

ELECTRICAL CONDUCTIVITY OF MIXED ADDITIVE FUELS (WIDE-CUT TYPE)

Sample No. FLO \ Temp. °C	Electrical Conductivity, pS/m 23° A	26° B	29° C	22° D	26° E
82036 (0.5 ppm Stadis 450)	252	260	259(433)	240	241
82036 (0.5 ppm ASA-3)	608	606			
82036 (0.5 ppm Stadis 450)	252	260	138(226)	142	119
81380 (0.5 ppm ASA-3)	166	192			
81378 (0.5 ppm Stadis 450)	89	84	138(141)	117	126
81378 (0.5 ppm ASA-3)	195	198			
81378 (0.5 ppm Stadis 450)	89	84	126(162)	117	120
81374 (0.5 ppm ASA-3)	236	240			
81375 (0.5 ppm Stadis 450)	70	50	63(145)	75	50
81375 (0.5 ppm ASA-3)	236	240			

A: Conductivities as measured at end of temperature cycling program (June 1982).

B: Conductivities measured immediately prior to mixing (July 1982).

C: Conductivity measured immediately after mixing equal volumes of each fuel. Values in parenthesis are calculated from B on basis of 50:50 mix.

D. Conductivity measured approximately two weeks after mixing.

E. Conductivity measured two days after cooling through 4°C, -16°C and -32°C cycles and restoring to room temperature.

TABLE 11

ELECTRICAL CONDUCTIVITY OF MIXED ADDITIVE FUELS (DIESEL FUELS)

<table>
<tr><th rowspan="2">Temp. °C
Sample No.
FLO</th><th colspan="6">Electrical Conductivity, pS/m</th></tr>
<tr><th>24°
A</th><th>24°
B</th><th>29°
C</th><th>22°
D</th><th>26°
E</th><th>21°
F</th></tr>
<tr><td>81382 (2 ppm Stadis 450)</td><td>101</td><td>107</td><td rowspan="2">144(113)</td><td rowspan="2">100</td><td rowspan="2">124</td><td rowspan="2">95</td></tr>
<tr><td>81382 (2 ppm ASA-3)</td><td>101</td><td>118</td></tr>
<tr><td>81382 (2 ppm Stadis 450)</td><td>101</td><td>107</td><td rowspan="2">171(118)</td><td rowspan="2">124</td><td rowspan="2">148</td><td rowspan="2">115</td></tr>
<tr><td>81381 (2 ppm ASA-3)</td><td>144</td><td>129</td></tr>
<tr><td>81381 (2 ppm Stadis 450)</td><td>140</td><td>132</td><td rowspan="2">158(131)</td><td rowspan="2">120</td><td rowspan="2">140</td><td rowspan="2">113</td></tr>
<tr><td>81381 (2 ppm ASA-3)</td><td>144</td><td>129</td></tr>
</table>

A: Conductivities as measured at end of temperature cycling program (May 1982).

B: Conductivities as measured immediately prior to mixing (July 1982).

C: Conductivity measured immediately after mixing equal volumes of each fuel. Values in parenthesis are calculated from B on basis of 50:50 mix.

D. Conductivity measured approximately two weeks after mixing.

E: Conductivity measured after cooling through 4°C, −16°C and −32°C cycles and restoring to room temperature.

F: Conductivity measured four days after heating to 43°C and restoring to room temperature.

6.7 Redoping Fuels with Stadis 450

The results presented in Tables 12 and 13 show the conductivity response obtained when further treatment with Stadis 450 is used on fuels that have been originally treated with the same additive and subject to temperature cycling. These results show that the increase in conductivity obtained is in general equal and in some cases slightly better than would be predicted from the original additive treatment. The increased conductivity also appears to be reasonably stable over a subsequent 15 day storage period. It would therefore appear that if a need arises to redope a Jet A-1 or Jet B type jet fuel the original response can be used to obtain an approximate idea of the Stadis 450 concentration required for redoping.

TABLE 12

REDOPING KEROSINE FUELS WITH STADIS 450

Sample No. FLO \ Days After Additive Treatment	Original Conductivity				Redoped with (ppm)	Conductivity After Redoping		
	1	20	37*	188		2 hrs	1	15
81371 + 0.5 ppm Stadis 450	117	105	82	90	1.0 Stadis 450	354	346	314
81371 + 1.0 ppm Stadis 450	256	272	239					
81371 + 2.0 ppm Stadis 450	501	540	497					
81372 + 0.5 ppm Stadis 450	160	143	132	120	0.8 Stadis 450	325	314	305
81372 + 1.0 ppm Stadis 450	310	302	302					
81374 + 1.0 ppm Stadis 450	122	120**	92	34	2.0 Stadis 450	296	268	237
81374 + 2.0 ppm Stadis 450	285	285**	228					
81377 + 2.0 ppm Stadis 450	215	167**	158	131	2.0 Stadis 450	461	454	403
82037 + 1.0 ppm Stadis 450	99	76*	37					
82037 + 2.0 ppm Stadis 450	292	247*	226	252	1.2 Stadis 450	468	464	430

* After cold and hot cycle

** 23 days

TABLE 13

REDOPING WIDE-CUT FUELS WITH STADIS 450

Sample No. FLO / Days After Additive Treatment	Original Conductivity				Redoped with (ppm)	Conductivity After Redoping		
	1	22	32	106		2 hrs	1	15
81378 + 0.5 ppm Stadis 450	153	80	86					
81378 + 1 ppm Stadis 450	307	228	242	253	0.4 Stadis 450	414	393	350
81379 + 0.5 ppm Stadis 450	150	96	97	74	1.0 Stadis 450	470	487	386
81379 + 1.0 ppm Stadis 450	307	252	265	224	0.4 Stadis 450	399	422	330
81379 + 2.0 ppm Stadis 450	636	626	663					
81380 + 0.5 ppm Stadis 450	105	102	27					
81380 + 1.0 ppm Stadis 450	167	164	68	116	1.5 Stadis 450	430	416	321
81380 + 2.0 ppm Stadis 450	344	326	192	239	0.8 Stadis 450	435	432	328

6.8 Comparison of ASA-3 and ASA-350

The comparison of calculated concentrations (mg/1) to produce 100 pS/m using ASA-3 and ASA-350 presented in Table 14 shows that variable results were obtained. In the majority of cases the agreement is quite reasonable, especially if the differences in response of the same additive at different dosage rates is considered. Where differences between ASA-3 and ASA-350 exist there does not appear to be any trend establishing which is the more effective.

As previously noted the comparison between the additives was made by comparing ASA-3 response with the ASA-3 data used to produce temperature/conductivity coefficients. This procedure resulted in a time-period of approximately six months elapsing between the two sets of measurements. The evaluation of static dissipator additives, as previously noted, is fraught with several possible sources of inaccuracy and the introduction of a time element may also be detrimental, since amongst other factors, it is possible that some slight oxidation of the fuels may occur. Because of the work load imposed by the program as a whole it was not possible to conduct the comparison in any other manner.

A comparison of the overall average temperature/conductivity coefficients using ASA-3 and ASA-350 shown in Table 15 indicates that generally speaking the same relationship between temperature and conductivity exists for both.

TABLE 14

COMPARISON OF ASA-3 AND ASA-350 CONCENTRATIONS TO PRODUCE 100 pS/m

	Concentrations of ASA-3 or ASA-350 to Produce 100 pS/m at 21°C*				
	ASA-3			ASA-350	
Dosage, mg/l →	**2.0**	**1.0**	**0.5**	**6.0**	**2.0**
FLO81379 (Jet A-1)					
1 day	0.25	0.29	0.36	0.63(0.32)	0.26(0.13)
21 days	0.29	0.46	0.68	0.76(0.38)	0.34(0.17)
Dosage, mg/l →				**3.0**	**1.5**
FLO81372 (Jet A-1)					
1 day	0.33	0.27	0.23	0.38(0.19)	0.29(0.15)
21 days	0.30	0.27	0.26	0.51(0.26)	0.43(0.22)
Dosage, mg/1 →				**1.6**	**0.8**
FLO81375 (Jet A-1)					
1 day	0.26	0.22	0.20	0.44(0.22)	0.40(0.22)
21 days	0.16	0.13	0.13	0.32(0.16)	0.35(0.18)
Dosage, mg/1 →				**1.6**	**0.8**
FLO81378 (Jet B)					
1 day	0.26	0.25	0.24	0.54(0.27)	0.58(0.29)
21 days	0.20	0.17	0.18	0.50(0.25)	0.64(0.32)
Dosage, mg/1 →				**1.2**	**0.6**
FLO82036 (Jet B)					
1 day		0.10	0.09	0.23(0.12)	0.23(0.12)
21 days		0.10	0.09	0.26(0.13)	0.31(0.16)
Dosage, mg/1 →				**4.0**	**2.0**
FLO81381 (Diesel)					
1 day	1.40	1.15	0.90	1.63(0.82)	1.43(0.72)
21 days	1.39	1.25	1.04	1.79(0.90)	1.83(0.92)

* Values in parenthesis based on assumption ASA-350 is half strength of ASA-3.

TABLE 15

COMPARISON OF TEMPERATURE/CONDUCTIVITY COEFFICIENTS (n) FOR ASA-3 AND ASA-350

	Average Temperature Coefficient Over Temperature Range – 33°C to +42°C	
	n(ASA-3)	n(ASA-350)
Jet A-1		
FLO81370	0.014	0.014
FLO81372	0.014	0.017
FLO81375	0.017	0.015
Diesel Fuel		
FLO81381	0.023	0.024
Jet B		– 33°C to 23°C
FLO81378	0.018	0.016
FLO82036	0.011	0.011

7.0 CONCLUSIONS

Several conclusions have been derived from the separate parts of the program and have been covered in the preceding paragraphs.

Two specific conclusions reached however are:

(a) The value of the temperature/conductivity coefficient range of 0.009-0.018 quoted in the Canadian aviation fuel specification is reasonably accurate. The range quoted however is too general and does not take into account

(i) Differences in the coefficient between fuel types, in this case between wide-cut fuels and kerosine fuels.

(ii) The difference in coefficients for the two additives.

(iii) Extreme high and low temperature effects on the coefficient.

(b) Specification requirements that quote an acceptable conductivity range of 50-450 pS/m on delivery to the purchaser do not necessarily provide adequate protection in terms of the electrical conductivity that may have been obtained during refuelling. In locations where fuel is supplied in summer and stored into a winter period, conductivity depletion may be sufficient to create a more hazardous situation than that encountered with untreated fuel.

8.0 RECOMMENDATIONS

(a) The data contained in this report should be summarized and presented in graphical form to cover the differences noted in Para. 7(a)(i)(ii) and (iii). This summarized version, including typical graphs, should be made available as a 3-GP-0 Test Method.

(b) The current values of 0.009-0.018 should be deleted from the fuel specifications and replaced by a reference to the recommended 3-GP-0 Test Method.

9.0 REFERENCES

1. *Turbine Fuel, Aviation, Wide-Cut-Type.* National Standard of Canada, CAN2-3.22-M80.

2. *Turbine Fuel, Aviation, Kerosine Type.* National Standard of Canada, CAN2-3.22-M81.

3. Henry, C.P. — *Low Temperature Conductivity Performance of Canadian Fuels Containing Conductivity Improver Additives.* E.I. duPont de Nemours & Co., Wilmington, DE PLMR-29-82. September 1982.

4. Gardner, L., Moon, G. — *Investigation of the Effect of Sample Variance Upon the Measurement of the Electrical Conductivity of Aviation Turbine Fuel.* NRC, NAE Aeronautical Report LR-473, National Research Council Canada, April 1967.

10.0 ACKNOWLEDGEMENT

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APPENDIX A

ELECTRICAL CONDUCTIVITY vs TEMPERATURE (TOTAL DATA)

TABLE A-1

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: KEROSINE TYPE FUELS (NRC DATA)

Sample No. FLO	Additive mg/l	Electrical Conductivity, pS/m, Measured at °F/°C							
		70/21	73/23	37/3	4/-16	-28/-33	73/23	107/42	72/22
81370 Jet A-1	Stadis 450								
	0.5	23	17	7	3	2	15	37	18
	1.0	58	24	11	6	3	22	50	26
	2.1	158	100	49	18	12	55	75	45
	ASA-3								
	0.5	140	74	41	20	9	51	65	38
	1.0	346	226	115	60	28	200	262	145
	2.0	787	707	352	165	74	624	885	454
		70/21	73/23	37/3	4/-16	-29/-34	73/28	107/42	70/21
81371 Jet A-1	Stadis 450								
	0.5	114	104	56	34	24	100	139	82
	1.0	250	271	159	97	56	284	397	239
	2.0	488	537	331	214	117	546	773	497
	ASA-3								
	0.5	99	101	58	35	19	94	156	96
	1.0	185	202	115	69	37	192	302	189
	2.0	359	384	226	153	82	392	625	387
		70/21	73/23	38/3	2/-17	-30/-34	73/23	107/42	71/22
81372 Jet A-1	Stadis 450								
	0.5	157	141	90	66	30	165	205	132
	1.0	304	302	199	149	74	360	460	302
	2.0	587	586	403	292	152	649	822	571
	ASA-3								
	0.5	217	190	105	48	24	164	260	150
	1.0	367	385	205	120	61	355	558	325
	2.0	605	704	391	241	117	699	1090	654

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TABLE A-1 (Cont'd)

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: KEROSINE TYPE FUELS
(NRC DATA)

Sample No. FLO	Additive mg/l	Electrical Conductivity, pS/m, Measured at °F/°C							
		70/21	73/23	37/3	0/-18	-30/-34	74/23	107/43	70/21
81373 Jet A-1	Stadis 450								
	0.5	102	94	57	32	22	92	123	81
	1.0	216	212	137	84	53	207	265	191
	2.0	446	445	312	199	126	434	540	410
	ASA-3								
	0.5	150	196	110	53	21	208	325	202
	1.0	315	398	233	133	64	435	690	443
	2.0	630	805	506	328	158	868	1360	890
		70/21	73/23	38/3	0/-18	-30/-34	74/23	107/42	70/21
81374 Jet A-1	Stadis 450								
	0.5	50	40	21	11	3	45	47	29
	1.0	118	112	60	26	10	120	157	92
	2.0	275	273	144	61	22	267	392	228
	ASA-3								
	0.5	100	116	61	23	8	100	138	80
	1.0	186	224	119	47	18	215	305	181
	2.0	408	487	276	122	46	490	768	492
		69/21	75/24	38/3	2/-17	-31/-35	76/24	105/40	75/23
81375 Jet A-1	Stadis 450								
	0.5	100	90	40	21	8	91	129	75
	1.0	205	206	100	46	17	196	289	173
	2.0	393	409	203	92	38	381	573	350
	ASA-3								
	0.5	248	424	226	83	31	353	503	321
	1.0	440	829	443	166	57	790	143	736
	2.0	770	1370	706	303	101	1489	2000+	1424

TABLE A-1 (Cont'd)

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: KEROSINE TYPE FUELS (NRC DATA)

Sample No. FLO	Additive mg/l	Electrical Conductivity, pS/m, Measured at °F/°C							
		69/21	75/24	38/3	2/-17	-31/-35	76/24	105/41	73/23
81376 Jet A-1	Stadis 450								
	0.5	87	44	22	15	5	48	59	33
	1.0	187	128	66	46	16	152	40	127
	2.0	390	336	188	128	49	356	504	328
	ASA-3								
	0.5	130	206	110	46	19	164	262	160
	1.0	250	440	249	167	40	400	594	383
	2.0	478	768	456	240	83	782	1155	785
		69/21	75/24	38/3	2/-17	-30/-34	75/24	105/41	74/23
81377 Jet A-1	Stadis 450								
	0.5	27	24	13	6	3	17	32	17
	1.0	67	56	34	21	12	50	69	46
	2.0	210	176	103	74	35	182	232	166
	ASA-3								
	0.5	58	63	35	17	6	51	80	48
	1.0	136	139	80	38	16	126	185	119
	2.0	298	326	185	85	35	303	435	294
		69/21	75/24	38/3	2/-17	-30/-34	75/24	105/41	74/23
82037 Jet A-1	Stadis 450								
	0.5	44	21	12	7	2	19	36	22
	1.0	96	81	46	18	6	38	58	39
	2.0	283	262	149	84	37	257	368	240
	ASA-3								
	0.5	117	87	39	14	7	44	68	40
	1.0	304	250	117	41	17	153	276	164
	2.0	776	732	360	143	57	640	1040	643

TABLE A-2

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: WIDE-CUT TYPE FUELS (NRC DATA)

Sample No. FLO	Additive mg/l	Electrical Conductivity, pS/m Measured at °F/°C					
		80/27	73/23	38/3	5/-15	-24/-31	74/23
81378 Jet A-1	Stadis 450						
	0.5	186	83	64	35	19	89
	1.0	373	237	164	92	45	252
	2.0	754	597	418	243	123	630
	ASA-3						
	0.5	252	298	158	70	34	295
	1.0	503	617	350	151	68	655
	2.0	938	1060	688	298	128	1175
		80/27	73/23	38/3	4/-16	-25/-32	74/23
81379 Jet B	Stadis 450						
	0.5	174	99	76	49	26	100
	1.0	357	260	201	138	73	273
	2.0	739	645	506	359	197	683
	ASA-3						
	0.5	284	288	160	86	40	236
	1.0	546	583	376	204	102	546
	2.0	1069	1195	818	466	229	1263
		80/27	73/23	38/3	5/-15	-25/-32	74/23
81380* Jet B	Stadis 450						
	0.5	126	106	20	12	9	28
*Initial Conductivity ≈ 25 pS/m at 75°F	1.0	201	170	51	35	23	70
	2.0	413	338	134	96	59	199
	ASA-3						
	0.5	295	210	111	57	24	166
	1.0	592	400	226	115	48	332
	2.0	1292	859	553	266	110	840

TABLE A-2 (Cont'd)

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: WIDE-CUT TYPE FUELS
(NRC DATA)

Sample No. FLO	Additive mg/l	Electrical Conductivity, pS/m Measured at °F/°C					
		81/27	74/23	39/4	6/-14	-25/-32	74/23
82036 Jet B	Stadis 450						
	0.5	311	258	227	210	160	252
	1.0	579	494	440	408	310	473
	2.0	1159	993	900	839	640	955
	ASA-3						
	0.5	670	620	401	248	154	608
	1.0	1210	1207	858	550	324	1249
	2.0	2000+	2000+	1760	1185	678	2000+

TABLE A-3

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: DIESEL FUELS
(NRC DATA)

Sample No. FLO	Additive mg/l	Electrical Conductivity, pS/m, Measured at °F/°C							
		69/21	75/24	38/3	2/-17	-29/-24	76/24	105/41	76/24
81381* Fuel Oil	Stadis 450								
	0.5	56	66	27	7	2	66	130	67
*Initial	1.0	83	97	37	11	3	94	189	98
Conductivity	2.0	122	142	55	17	5	131	265	140
5 pS/m at	ASA-3								
5°F	0.5	52	56	21	7	3	49	98	49
	1.0	82	97	35	12	4	83	163	84
	2.0	136	172	65	21	5	146	274	144
		81/27	74/23	35/2	5/-15	-25/-32	74/23	109/43	75/24
81382* Fuel Oil	Stadis 450								
	0.5	53	44	15			45	107	45
*Initial	1.0	78	66	21	Below Pour Point		65	164	67
Conductivity	2.0	114	99	31	Measurements		97	255	101
13 at 74°F	ASA-3				Not Possible				
	0.5	79	49	16			51	119	46
	1.0	117	73	24			75	182	71
	2.0	188	120	38			122	289	111

TABLE A-4

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: KEROSINE FUELS (DuPont DATA)

Sample No. FLO	Additive ppm	Electrical Conductivity, pS/m Measured at °F/°C *						
		68/20	110/43	67/19	40/4	-2/-19	-30/-34	69/21
81370 Jet A-1	Stadis 450							
	2.3	73	110	66	41	20	8	92
	4.6	220	235	83	57	40	47	367
	ASA-3							
	0.43	95	142	85	48	23(-3)	12	82
	1.7	282	380	217	80	84(-3)	35(-29)	258
81371 Jet A-1	Stadis 450							
	0.57	78	140	78	42	28	15	85
	2.0	375	604	350	250	145(-1)	82	305
	ASA-3							
	0.29	81	130	80	30	17	10	62
	1.4	370	660	385	225	120(0)	75(-29)	272
81372 Jet A-1	Stadis 450							
	0.86	100	145	84	55	40	20	84
	1.7	410(66)	585	390	318	214(-1)	107(-32)	442
	ASA-3							
	0.14	78	115	70	40	22	10(-28)	50
	1.1	395(66)	600	350	230	114(0)	63	297
		66/19						
81373 Jet A-1	Stadis 450							
	0.43	105(68)	173	95	65	33(-3)	18(-29)	95
	2.0	412	540	405(66)	340	252	156	440
	ASA-3							
	0.29	95(68)	135	90	60	42	28(-28)	86
	1.1	525	990	495	330	194	92	485

TABLE A-4 (Cont'd)

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: KEROSINE FUELS
(DuPont DATA)

Sample No. FLO	Additive ppm	Electrical Conductivity, pS/m Measured at °F/°C *						
		66/19	110/43	67/19	40/4	0/-18	-30/-34	69/21
81374 Jet A-1	Stadis 450							
	2.4	95(68)	130	73	55	24(-3)	10	85
	3.7	340	555	312(66)	225	130	44(-32)	355
	ASA-3							
	0.57	96(68)	135	75	48	25(-1)	11	71
	1.7	335	555	290	190	90	39(-29)	343
						-1/-18	-32/-36	
81375 Jet A-1	Stadis 450							
	0.86	85(68)	150	81	49	22(-2)	6(-31)	95
	2.3	380	640	360(66)	235	115(-3)	48	395
	ASA-3							
	0.14	80(68)	130	58	53	30	10(-30)	92
	0.86	450	850	445	255	83	30(-28)	405
		68/20					-30/-34	
81376 Jet A-1	Stadis 450							
	1.1	92	155	87	60	28(0)	10	87
	2.4	407(67)	660	342(66)	320	155	68	395
	ASA-3							
	0.29	88	155	86	45	20(-2)	23(-28)	96
	1.1	342(66)	650	340	188	72(-2)	20(-28)	248
		73/23			42/6	3/-16	-28/-33	73/23
81377 Jet A-1	Stadis 450							
	1.7	93	137	76	77	44(4)	27	106
	3.7	412	585	345	315	156	78	435
	ASA-3							
	0.72	92	138	85	53	20	8	69
	2.3	383	532	341	208	82(4)	30	328
82037 Jet A-1	Stadis 450							
	1.7	68	107	53	33	20	8	54
	3.6	330	457	258	140	73	38	270
	ASA-3							
	0.43	74	110	58	28	11	4	27
	1.43	318	543	255	144	60	27	218

* Values in parenthesis actual measurement temperature, °F

TABLE A-5

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: WIDE-CUT FUELS (DuPont DATA)

Sample No. FLO	Additive ppm	Electrical Conductivity, pS/m Measured at °F/°C						
		73/23	110/43	67/19	42/6	3/-16	-28/-33	73/23
82036 Jet B	Stadis 450							
	0.14	80	114	63(66)	48	42	35	76
	0.86	440	554	420	390	352	275(-29)	505
	ASA-3							
	0.14	143	202	134	95	54	44	107
	0.43	508	670	450	343	210	120	460
						2/-17	-27/-33	
81378 Jet B	Stadis 450							
	0.43	82	127	70	67	34(3)	17	65
	1.4	430	700	370	230	148	80	400
	ASA-3							
	0.29	100	168	85	60	25	7	70
	0.57	370	565	320	230	77	32	295
						0/-18	-28/-33	
81379 Jet B	Stadis 450							
	0.43	80	112	79	60	42(-1)	20	62
	1.3	370	530	340	294	180	98	371
	ASA-3							
	0.29	101	163	102	67	30(-1)	15	85
	0.72	370	540	360	242	100	51	275
						-1/-18		
81380 Jet B	Stadis 450							
	1.0	106	140	95	70	51	34	85
	2.9	320	459	280	253	142	88	435
	ASA-3							
	0.29	90	134	80	55	25(0)	5	80
	1.1	435	675	380	305	105(0)	48	368

TABLE A-6

ELECTRICAL CONDUCTIVITY vs TEMPERATURE: DIESEL FUELS

(DuPont DATA)

Sample No. FLO	Additive ppm	Electrical Conductivity, pS/m Measured at °F/°C						
		73/23	110/43	67/19	42/6	-1/-18	-28/-33	73/23
81381 Diesel Fuel	Stadis 450							
	1.3	90	200	74	39	11	waxy	92
	8.6	346	668	284	153	44	waxy	295
	ASA-3							
	1.0	80	165	64	36	12	waxy	83
	4.3	280	533	219	110	30(0)	waxy	218
						0/-18	-30/-34	
81382 Diesel Fuel	Stadis 450							
	2.7	100	268	81	43	waxy	waxy	100
	8.6	195	521	154	75	waxy	waxy	187
	ASA-3							
	1.3	80	180	61	32	waxy	waxy	78
	7.2	233	528	177	82	waxy	waxy	210

APPENDIX B

TEMPERATURE/CONDUCTIVITY COEFFICIENTS (TOTAL DATA)

TABLE B-1

TEMPERATURE/CONDUCTIVITY COEFFICIENTS (JET A-1 + STADIS 450) – NRC DATA

Additive	2.0 ppm Stadis 450								1.0 ppm Stadis 450								0.5 ppm Stadis 450							
Sample No. FLO / Temp °C	42 to -33	42 to 23	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR	42 to -33	42 to 23	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR	42 to -33	42 to 23	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR
81370	0.011	0.009	0.014	0.016	0.016	0.023	0.011	0.012	0.016	0.016	0.016	0.014	0.016	0.014	0.016	0.016	0.016	0.020	0.016	0.015	0.020	0.020	0.011	0.018
81371	0.011	0.007	0.011	0.011	0.011	0.011	0.014	0.011	0.011	0.009	0.013	0.011	0.011	0.013	0.013	0.011	0.011	0.009	0.011	0.013	0.013	0.013	0.009	0.011
81372	0.009	0.007	0.011	0.007	0.009	0.007	0.016	0.009	0.011	0.007	0.011	0.007	0.009	0.005	0.016	0.010	0.011	0.007	0.013	0.011	0.011	0.007	0.018	0.011
81373	0.009	0.005	0.007	0.009	0.007	0.009	0.013	0.008	0.009	0.007	0.011	0.011	0.009	0.011	0.013	0.009	0.009	0.007	0.011	0.011	0.011	0.012	0.009	0.010
81374	0.016	0.011	0.018	0.016	0.014	0.018	0.017	0.016	0.016	0.009	0.018	0.016	0.014	0.018	0.025	0.016	0.016	0.007	0.010	0.014	0.014	0.013	0.034	0.016
81375	0.020	0.011	0.018	0.014	0.014	0.018	0.022	0.016	0.016	0.011	0.018	0.016	0.014	0.016	0.023	0.017	0.016	0.011	0.018	0.016	0.018	0.014	0.023	0.016
81376	0.013	0.011	0.014	0.011	0.013	0.009	0.023	0.013	0.020	0.011	0.016	0.011	0.014	0.007	0.025	0.014	0.014	0.011	0.016	0.011	0.014	0.007	0.027	0.014
81377	0.011	0.007	0.013	0.009	0.011	0.007	0.018	0.011	0.016	0.011	0.011	0.013	0.011	0.011	0.014	0.010	0.014	0.016	0.014	0.013	0.013	0.016	0.018	0.013
82037	0.013	0.011	0.014	0.013	0.013	0.013	0.020	0.013	0.013	0.011	0.018	0.013	0.013	0.020	0.027	0.013	0.016	0.014	0.018	0.011	0.013	0.013	0.031	0.015
Average	0.013	0.009	0.013	0.013	0.013	0.013	0.018	0.012	0.014	0.010	0.015	0.012	0.012	0.013	0.019	0.013	0.014	0.011	0.015	0.013	0.014	0.013	0.020	0.014
Minimum	0.009	0.005	0.007	0.007	0.007	0.077	0.011	0.008	0.009	0.007	0.011	0.007	0.009	0.005	0.013	0.009	0.009	0.007	0.011	0.011	0.011	0.007	0.009	0.011
Maximum	0.020	0.011	0.018	0.016	0.016	0.023	0.023	0.016	0.020	0.016	0.018	0.018	0.016	0.020	0.027	0.017	0.016	0.020	0.020	0.018	0.020	0.020	0.034	0.018

TABLE B-2

TEMPERATURE/CONDUCTIVITY COEFFICIENTS (JET A-1 + ASA-3) — NRC DATA

Additive	2.0 ppm ASA-3								1.0 ppm ASA-3								0.5 ppm ASA-3							
Sample No. FLO / Temp. °C	42 to -33	42 to 23	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR	42 to -33	42 to 23	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR	42 to -33	42 to 23	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR
81370	0.014	0.011	0.018	0.014	0.014	0.018	0.020	0.015	0.013	0.009	0.014	0.014	0.014	0.016	0.018	0.013	0.011	0.007	0.014	0.013	0.013	0.016	0.020	0.012
81371	0.011	0.011	0.013	0.011	0.011	0.009	0.014	0.012	0.013	0.011	0.013	0.011	0.013	0.013	0.014	0.012	0.013	0.011	0.013	0.011	0.013	0.013	0.014	0.012
81372	0.013	0.011	0.014	0.013	0.013	0.011	0.018	0.013	0.013	0.011	0.014	0.013	0.014	0.011	0.016	0.013	0.014	0.011	0.014	0.014	0.013	0.016	0.016	0.014
81273	0.013	0.011	0.013	0.011	0.011	0.009	0.020	0.012	0.014	0.011	0.014	0.011	0.013	0.011	0.020	0.013	0.016	0.011	0.018	0.014	0.013	0.014	0.023	0.016
81374	0.016	0.011	0.018	0.014	0.013	0.016	0.025	0.016	0.016	0.011	0.018	0.016	0.014	0.020	0.025	0.016	0.022	0.009	0.020	0.018	0.014	0.020	0.027	0.016
81375			0.020	0.018	0.014	0.018	0.025	0.019	0.018	0.011	0.020	0.018	0.013	0.022	0.025	0.017	0.016	0.011	0.018	0.016	0.013	0.022	0.023	0.016
81376	0.014	0.011	0.016	0.013	0.011	0.014	0.025	0.015	0.016	0.011	0.018	0.014	0.013	0.018	0.023	0.016	0.014	0.013	0.018	0.014	0.013	0.018	0.022	0.015
81377	0.014	0.011	0.016	0.014	0.013	0.016	0.022	0.016	0.014	0.011	0.016	0.014	0.011	0.016	0.022	0.014	0.014	0.014	0.018	0.014	0.013	0.016	0.027	0.014
82037	0.016	0.013	0.018	0.018	0.014	0.020	0.022	0.017	0.016	0.014	0.018	0.018	0.016	0.023	0.022	0.016	0.013	0.011	0.016	0.016	0.016	0.022	0.016	0.014
Average	0.014	0.011	0.016	0.014	0.013	0.015	0.021	0.015	0.015	0.011	0.016	0.014	0.013	0.017	0.021	0.014	0.015	0.011	0.017	0.014	0.013	0.017	0.021	0.014
Minimum	0.011	0.011	0.013	0.011	0.011	0.009	0.014	0.012	0.013	0.009	0.013	0.011	0.011	0.011	0.014	0.012	0.011	0.007	0.013	0.011	0.013	0.013	0.016	0.012
Maximum	0.016	0.013	0.020	0.018	0.014	0.020	0.025	0.019	0.018	0.014	0.020	0.018	0.016	0.023	0.025	0.017	0.022	0.014	0.020	0.018	0.016	0.022	0.027	0.016

TABLE B-3

TEMPERATURE/CONDUCTIVITY COEFFICIENTS (JET B + STADIS 450) -- NRC DATA

Additive	2.0 ppm Stadis 450						1.0 ppm Stadis 450						0.5 ppm Stadis 450					
Sample No. FLO / Temp. °C	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR
81378	0.013	0.011	0.007	0.013	0.018	0.012	0.014	0.011	0.009	0.014	0.020	0.013	0.013	0.011	0.005	0.014	0.016	0.011
81379	0.009	0.007	0.005	0.007	0.016	0.009	0.011	0.007	0.005	0.009	0.016	0.010	0.011	0.007	0.005	0.011	0.016	0.010
81380	0.011	0.011	0.020	0.007	0.013	0.012	0.013	0.013	0.027	0.009	0.011	0.013	0.014	0.018	0.038	0.011	0.007	0.015
82036	0.004	0.002	0.002	0.002	0.007	0.003	0.004	0.002	0.002	0.002	0.007	0.003	0.004	0.002	0.004	0.002	0.007	0.003
Average	**0.009**	**0.008**	**0.009**	**0.007**	**0.014**	**0.009**	**0.011**	**0.008**	**0.011**	**0.009**	**0.014**	**0.010**	**0.011**	**0.010**	**0.013**	**0.010**	**0.012**	**0.010**
Minimum	**0.004**	**0.002**	**0.002**	**0.002**	**0.007**	**0.003**	**0.004**	**0.002**	**0.002**	**0.002**	**0.007**	**0.003**	**0.004**	**0.002**	**0.004**	**0.002**	**0.007**	**0.003**
Maximum	**0.013**	**0.011**	**0.020**	**0.012**	**0.018**	**0.012**	**0.014**	**0.013**	**0.027**	**0.014**	**0.020**	**0.013**	**0.014**	**0.018**	**0.038**	**0.014**	**0.016**	**0.015**

TABLE B-4

TEMPERATURE/CONDUCTIVITY COEFFICIENTS (JET B + ASA-3) — NRC DATA

Additive	2.0 ppm ASA-3						1.0 ppm ASA-3						0.5 ppm ASA-3					
Sample No. FLO / Temp. °C	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR	23 to -33	23 to -18	23 to 3	3 to -18	-18 to -33	nR
81378	0.018	0.014	0.009	0.020	0.023	0.017	0.018	0.016	0.013	0.020	0.022	0.018	0.018	0.016	0.014	0.020	0.020	0.017
81379	0.013	0.011	0.009	0.013	0.020	0.013	0.014	0.011	0.009	0.014	0.018	0.013	0.014	0.012	0.013	0.014	0.020	0.014
81380	0.016	0.013	0.009	0.016	0.023	0.016	0.014	0.014	0.013	0.016	0.023	0.016	0.016	0.014	0.014	0.016	0.023	0.016
82036				0.009	0.014	0.012	0.011	0.009	0.007	0.011	0.013	0.010	0.011	0.011	0.009	0.011	0.013	0.011
Average	0.016	0.013	0.009	0.015	0.020	0.015	0.014	0.013	0.011	0.015	0.019	0.014	0.015	0.014	0.013	0.015	0.019	0.015
Minimum	0.013	0.011	0.009	0.009	0.014	0.012	0.011	0.009	0.007	0.011	0.013	0.010	0.011	0.011	0.009	0.011	0.013	0.011
Maximum	0.018	0.014	0.009	0.020	0.023	0.017	0.018	0.016	0.013	0.020	0.023	0.018	0.018	0.016	0.014	0.020	0.023	0.017

TABLE B-5

TEMPERATURE/CONDUCTIVITY COEFFICIENTS (DIESEL FUELS) — NRC DATA

Additive	2.0 ppm Stadis 450							
Sample No. FLO \ Temp. °C	42 to −33	42 to 23	23 to −33	23 to −18	23 to 3	3 to −18	−18 to −33	nR
81381	0.023	0.018	0.025	0.022	0.020	0.025	0.031	0.023
81382		0.022			0.025			0.023
Average	0.023	0.020	0.025	0.022	0.023	0.025	0.031	0.023

Additive	1.0 ppm Stadis 450							
Sample No. FLO \ Temp. °C	42 to −33	42 to 23	23 to −33	23 to −18	23 to 3	3 to −18	−18 to −33	nR
81381	0.023	0.018	0.025	0.023	0.020	0.027	0.032	0.024
81382		0.022			0.025			0.022
Average	0.023	0.020	0.025	0.023	0.023	0.027	0.032	0.023

Additive	0.5 ppm Stadis 450							
Sample No. FLO \ Temp. °C	42 to −33	42 to 23	23 to −33	23 to −18	23 to 3	3 to −18	−18 to −33	nR
81381	0.020	0.018	0.022	0.022	0.022	0.023	0.022	0.021
81382		0.022			0.025			0.022
Average	0.020	0.020	0.022	0.022	0.023	0.023	0.022	0.022

Additive	2.0 ppm ASA-3							
Sample No. FLO \ Temp. °C	42 to −33	42 to 23	23 to −33	23 to −18	23 to 3	3 to −18	−18 to −33	nR
81381	0.023	0.013	0.025	0.022	0.020	0.025	0.036	0.023
81382		0.022			0.025			0.022
Average	0.023	0.020	0.025	0.022	0.023	0.025	0.036	0.023

Additive	1.0 ppm ASA-3							
Sample No. FLO \ Temp. °C	42 to −33	42 to 23	23 to −33	23 to −18	23 to 3	3 to −18	−18 to −33	nR
81381	0.022	0.016	0.023	0.022	0.022	0.023	0.027	0.022
81382		0.322			0.023			0.022
Average	0.022	0.019	0.023	0.022	0.023	0.023	0.027	0.022

Additive	0.5 ppm ASA-3							
Sample No. FLO \ Temp. °C	42 to −33	42 to 23	23 to −33	23 to −18	23 to 3	3 to −18	−18 to −33	nR
81381	0.020	0.018	0.022	0.022	0.022	0.023	0.022	0.021
81382		0.022			0.025			0.022
Average	0.020	0.020	0.022	0.022	0.023	0.023	0.022	0.022

TABLE B-6

TEMPERATURE/CONDUCTIVITY COEFFICIENTS (JET A-1) — DUPONT DATA

High Initial Conductivities

Sample No. FLO	n (43 to 4°C)		n (4 to 34°C)		nR	
	Stadis 450	ASA-3	Stadis 450	ASA-3	Stadis 450	ASA-3
81370	0.0158*	0.0083	0.0022*	0.0186	0.0116*	0.0132
81371	0.0099	0.0120	0.0124	0.0124	0.0111	0.0121
81372	0.0068	0.0107	0.0118	0.0145	0.0090	0.0127
81373	0.0052	0.0123	0.0087	0.0143	0.0067	0.0126
81374	0.0100	0.0120	0.0177	0.0179	0.0135	0.0150
81375	0.0112	0.0134	0.0172	0.0246	0.0142	0.0190
81376	0.0084	0.0139	0.0173	0.0258	0.0121	0.0193
81377	0.0071	0.0108	0.0156	0.0216	0.0113	0.0167
82037	0.0136	0.0153	0.0146	0.0187	0.0147	0.0170
Average Value	**0.0098**	**0.0120**	**0.0130**	**0.0187**	**0.0116**	**0.0150**
Median Value	**0.0099**	**0.0120**	**0.0146**	**0.0186**	**0.0116**	**0.0150**

Low Initial Conductivities

Sample No. FLO	n (43 to 4°C) Stadis 450	n (43 to 4°C) ASA-3	n (4 to 34°C) Stadis 450	n (4 to 34°C) ASA-3	nR Stadis 450	nR ASA-3
81370	0.0110	0.0121	0.0182	0.0155	0.0150	0.0142
81371	0.0134	0.0175	0.0115	0.0123	0.0125	0.0159
81372	0.0108	0.0118	0.0113	0.0159	0.0106	0.0134
81373	0.0109	0.0091	0.0145	0.0088	0.0123	0.0089
81374	0.0096	0.0115	0.0190	0.0164	0.0144	0.0140
81375	0.0125	0.0100	0.0231	0.0186	0.0175	0.0135
81376	0.0106	0.0138	0.0200	0.0077	0.0148	0.0125
81377	0.0066	0.0110	0.0117	0.0211	0.0091	0.0163
82037	0.0135	0.0157	0.0158	0.0217	0.0142	0.0183
Average Value	**0.0110**	**0.0125**	**0.0161**	**0.0153**	**0.0134**	**0.0141**
Median Value	**0.0109**	**0.0118**	**0.0158**	**0.0159**	**0.0142**	**0.0140**

* High initital conductivity data for Stadis 450 with FLO81370 had a poor regression coefficient = 0.792 all other gave ≥ 0.95.

TABLE B-7

TEMPERATURE/CONDUCTIVITY COEFFICIENTS (JET B) — DUPONT DATA

High Initial Conductivities

Sample No. FLO	n (43 to 4°C)		n (4 to 34°C)		nR	
	Stadis 450	ASA-3	Stadis 450	ASA-3	Stadis 450	ASA-3
81378	0.0105	0.0103	0.0142	0.0223	0.0121	0.0165
81379	0.0068	0.0092	0.0123	0.0174	0.0091	0.0133
81380	0.0068	0.0090	0.0118	0.0207	0.0090	0.0149
82036	0.0022	0.0075	0.0040	0.0121	0.0037	0.0097
Average	**0.0065**	**0.0090**	**0.0105**	**0.0181**	**0.0085**	**0.0136**

Low Initial Conductivities

81378	0.0074	0.0118	0.0155	0.0243	0.0107	0.0175
81379	0.0072	0.0102	0.0122	0.0167	0.0087	0.0132
81380	0.0081	0.0102	0.0081	0.0268	0.0077	0.0175
82036	0.0097	0.0087	0.0036	0.0086	0.0066	0.0092
Average	**0.0081**	**0.0102**	**0.0099**	**0.0191**	**0.0084**	**0.0144**

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The Relationship Between Electrical Conductivity and Temperature of Aviation Turbine Fuels Containing Static Dissipator Additives

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DESCRIPTORS(KEY WORDS)/MOTS-CLÉS

1. Electrical conductivity — measurement
2. Fuels —,conductivity
3. Fuels — temperature effect
4. Electrostatics
5. Aircraft engines — fuel systems

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SUMMARY/SOMMAIRE

The relationship between the electrical conductivity and temperature of Canadian produced wide-cut and kerosine type aviation turbine fuels containing static dissipator additives has been evaluated.

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